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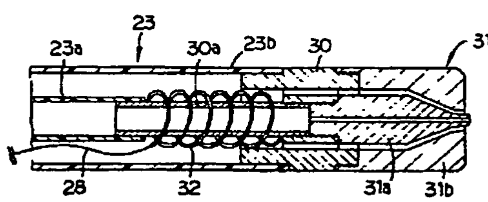
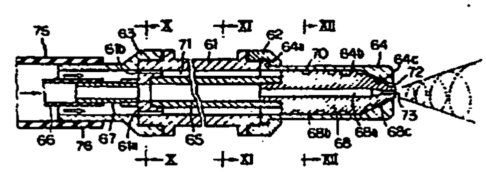
(54) **Method, apparatus and spray nozzle for coating the inner surface of long tubes of small diameter.**

(57) A coating method and apparatus for coating the inner surface of a long tube of small diameter, specifically tubes for a condenser. The coating is a type of spray coating wherein a long flexible supplying hose, longer than the long tube to be coated, is reciprocated in the long tube with a spray nozzle attached to the tip thereof for spraying the paint by the action of compressed air, from one end of the long tube to the other end thereof while spraying the paint in atomization. The long flexible supplying hose (22) of double structure or sometimes of triple structure is composed of a short heating pipe portion adjacent to the spray nozzle and a long flexible hose portion. The paint and compressed air supplied through separate passages in the supplying hose are heated to a predetermined temperature by an electrical heating means, for example, a sheathed heater (32) wound about an inside pipe (30a) of the heating pipe portion before the paint is sprayed. In the nozzle a nozzle insert (68) having a prism portion (68b), on the external surface of which at least one spiral groove (70) is formed, is inscribed to the inner surface of a hollow cylindrical space of a nozzle cap (64) of the above-mentioned nozzle. A plurality of straightly elongated grooves, formed between the inner surface of the nozzle cap (64) and the sides of the prism portion (68b) of the nozzle insert (68), and the spiral groove function to impart atomizing gas a straightly going force and a spirally going force, so as to spirally spray the paint supplied through a paint supply passage extending along the axis of the nozzle insert.





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METHOD AND APPARATUS FOR COATING THE INNER SURFACE OF LONG TUBES OF SMALL DIAMETER

This invention relates to a method and apparatus for coating the inner surface of long tubes of small diameter, and more particularly to a method applicable to protective coating of a heat exchanger tube or condenser tube employed in a condenser of a steam turbine, used for a power plant, being especially effective in performing the coating where the tube is in an installed condition in the plant, and to an apparatus therefor.

In power plants condensers have been traditionally used for cooling the exhaust gas (steam) of a stream-turbine to condense it and recycle the condensed water. In a condenser of such use thousands of or sometimes tens of thousands of long tubes of copper alloy, for example 5-40 m in length, having a small inner diameter on the order of 10-40 mm are incorporated as condenser tubes. Those tubes, which pass the cooling water such as sea water therethrough, are adapted to cool the exhaust steam passing thereoutside.

Those condenser tubes, which constantly pass the cooling liquid such as sea water containing corrosive substances richly at a fairly high flow speed, for example 1-2.5 m/sec., are susceptible to various types of corrosion or erosion corrosion. It is therefore necessary to cover or coat the whole inner (internal) surface of those tubes with a protective synthetic resin coating or paint for the purpose of corrosion-and-rust prevention. But the coating in this case is required to avoid degradation of the heat transfer therefrom, which is the essential condition of the condenser tube, by all means. For example a thin (on the order of 10-30 μ) and uniform coating film which will not deteriorate the heat transferring or exchanging capability is needed for the protective coating of a heat transfer tube such as a heat exchanger tube in a heat changer like a condenser.

With tubes having a thin coating film in the interior thereof it is sometimes necessary to repaint or recoat, before the life of the whole plant for example 20 or 30 years comes to an end, because the thin coated film (a) may be worn away after the tubes being installed in the plant to expose the base metal by a mere aging, (b) may be eroded by shells or sand particles contained in the sea water, or (c) may be worn acceleratively by the so-called sponge ball cleaning method taken to remove foreign matters stuck to the tube such as seaweeds. The interior coating of resin paint film of the tubes are sometimes shorter in life than the plant itself, and it must be periodically or occasionally repainted (recoated) particularly in an installed state in the plant.

Conventionally practiced methods, mostly used for painting the interior of relatively short tubes ranging the whole length thereof, that is, flow coating method of flowing paint through a tube or brush coating method of brushing paint directly on the inner surface of the tube, have been defective for being applied to long tubes of small diameter in being difficult in getting a uniform-thick coated film. Particularly the former method is not good when it is applied to a tube already installed in a condenser, because the tube can not be inclined for flowing out the superfluous paint. Practicability of both the methods are as a matter of fact hardly recognized at the present stage.

As another method with relatively high practicability and which seems to be available, paint nebulized or atomized by a spray gun is coated on the inner surface of a tube, And sometimes even a long neck spray gun with a length of 500 mm or so is inserted in the tube, but it is not free from a problem that the length of the tube to be effectively coatable by this spray gun is naturally restricted to some extent. Still another method, as a variation of the above for avoiding the problem, seems to be available, wherein a moving nozzle which is shiftable from one end of a tube to the other end while spraying the paint

is employed. In any way problems are still left unsolved as to what length of the tube interior can be well coated by the spray coating method. Even the latter, when it is applied to coating of the interior of a condenser tube of small diameter and large length, particularly in a heat exchanger tube of a condenser, leaves something to be desired. For example, as the coated film is apt to be largely influenced by temperature, humidity and other environmental conditions, it is very difficult to keep the film thickness at a desired uniform value in coating an already installed long tubes of small diameter where the necessary environmental conditions are almost out of control; uneven thickness or defective coating of the film may as a result take place there. When the tube to be coated is a long heat exchanger tube, varying of the thickness of the coated film is likely to cause variation of the heat conducting or transferring capability. So strict control of the environmental conditions for keeping the coating thickness even is of great importance.

Generally the thickness (t) of a coated film is regulated by an undermentioned formula,

$$t = \frac{q \times \alpha}{\pi \times Di \times v \times \rho}$$

wherein, q: discharge amount of the paint
α: solid ratio of the paint
Di: inner diameter of the tube to be coated
v: shifting rate of the spray nozzle
ρ: density of the coated film.

That is to say, the thickness (t) of the film is given as a function of the discharge amount (q) of the paint, solid ratio (α), i.e. of the solidified portion (component to be remained), of the paint, and the shifting rate (v) of the spray nozzle. Out of those (q) and (v) can be easily made constant independently of the environmental conditions of coating, but (α), the ratio of the solidified portion of the paint, is determined by the mixing ratio of the synthetic

resin, pigment, and solvent. Coating is however practiced generally, irrespective of the environmental temperature, at a most suitable paint viscosity for spraying. The viscosity of a film forming substance such as synthetic resin depends, on the other hand, upon the temperature, so it is necessary to vary the mixing ratio of the solvent in the paint according to the environmental temperature under which the coating is carried out so as to keep a constant viscosity of the paint to be coated. In other words, the value α in the general formula mentioned above is varied to consequently change the thickness (t) of the film.

Observing this problem from the view point of defects of the coated film, operation in the plants in cold districts or in a winter season draws particular attention. The solvent ratio must inevitably be raised in such cases because of the remarkable low level of the ambient temperature for getting the predetermined viscosity of the paint. This consequently results in occurrence of dripping or gathering of the paint toward the lower side of the tube due to elongation of the film forming time duration, insufficient curing of the coated film, remelting of the once solidified film in response to increasing of the solvent evaporating amount, and undesirable environmental pollution due to the evaporation of the solvent in large quantity.

Hot spray coating was proposed, on the other hand, to eliminate those disadvantages. Traditional technology of heating the paint or the air employed at the source thereof, be it by the paint heating method or the hot air spray method, is very impracticable from the view point of applying the same to the inner surface of long tubes of small diameter. Because, in the condenser tubes of large length already installed in a condenser or the like the distance from the paint reservoir to the end of the spray nozzle is not less than 20 m at the least, and consequently maintaining the temperature of the paint at a predetermined level is difficult. In case of the hot air spraying method, supply of the required hot air of large quantity, such as 200-500 ℓ/min.,

passing such a long distance, needs a huge equipment for elevating and maintaining the temperature to and at a necessary level. This is the Achilles heel of the hot spray coating method in the practical application thereof.

An ideal method for coating a thin film of uniform thickness to the inner surface of a long tube of small diameter has not been established. Protective coating is confronted at the present stage with many technical difficulties, particularly in case of an already installed condenser tube in the condenser. Actually the tubes the coating of which have been worn away due to the causes mentioned above in the running condition, have to be replaced by new completely coated ones, which causes a huge amount of working and material cost, bringing about a great loss.

On the other hand, the air spray coating method in the interior coating of a tube is usually limited to a case wherein the internal diameter of the tube is relatively large, the length of the tube is within 5 meters or so, and the thickness of the coated film is allowed as large as 50-200 μ. It is therefore employable only for the anti-corrosion coating of a tube or pipe used in flowing an ordinary fluid.

In the coating of the heat exchanger tubes for a condenser, so-called condenser tubes, thin and uniform film of coating on the order of 10-30 μ is required; and it must be executed in tubes of internal diameter as small as 10-40 mmφ and of length as large as 5-40 m. Such a situation has conventionally made the thin and uniform interior coating extremely difficult. Besides, the air spray coating method and apparatus was originally developed for the use over a plane surface. It is a very excellent method for coating a plane, but applying the same to the interior of a small diametered tube or pipe is very difficult, because it is not suitable for being shifted through the tube inside while uniformly and thinly coating the curved or circular interior surface.

In a spray gun which has been used in the air spray coating, a nozzle portion is said susceptible to sticking of

paint and dust in either the paint passage or air passage. Such sticking of paint and dust to the passages is liable to deteriorate the spraying (atomizing) condition due to the clogging thereof. It makes the spraying unstable, which naturally hampers a continuous and uniform coating to be executed smoothly. Besides, the clogging of the essential portions of the nozzle requires a breaking up for cleaning thereof, giving rise to another problem of increasing the man power to be consumed.

The present invention was made from such a background. It is therefore a primary object of this invention to provide an effective and practical method of coating the inner or internal surface of a long tube of small diameter and an apparatus therefor.

It is another object of this invention to provide an effective and practical method of protective coating to the inner surface of a long condenser tube of small diameter chiefly utilized in a condenser or the like in a power plant, particularly in an installed state in place, for giving a great financial benefit, and an apparatus therefor.

It is still another object of this invention to provide a method and apparatus for forming a protective coating with uniform film thickness of paint in the range 10-30 μ, applicable on the inner surface of condenser tubes used in a surface condenser without affecting the heat transfer performance thereof.

It is further object of this invention to provide a novel nozzle structure which is capable of forming a coated film of uniform thickness in either circumferential and axial direction on the inner surface of a tube, and stable in paint atomization or nebulization, even when the same is employed in a continuous spray coating operation, without any fear of clogging the nozzle mouth with the paint and dust.

Other objects of this invention will become apparent to those skilled in the art from the following detailed description of the preferred embodiments when read in connection with the accompanying drawings.

The present invention has developed a supplying hose, utilized in a type of spray coating for coating a long tube of small diameter, wherein a paint atomizing nozzle is moved from one end of the tube to the other end thereof, which supplying hose is longer than the tube to be coated for being inserted through the long tube when the coating is carried out, and the paint and the compressed air are respectively heated in the supplying hose to a predetermined temperature so that the heated paint is sprayed in an atomized state by the similarly heated compressed air through the nozzle. This invention has thus enabled the formation of a thin and uniform thick film on the inner surface of a long tube of small diameter, without producing any unevenness and other defects in the coated film.

According to this invention a supplying hose having a spray nozzle disposed on the tip thereof and passages for the paint and the compressed air is inserted into the long tube to be coated from one opening end thereof. When the nozzle has reached the other opening end of the long tube, the supplying hose is drawn back at a predetermined speed or rate toward the firstly inserted opening end, while performing the paint spraying from the nozzle. The paint and the air are respectively delivered from a paint reservoir and a compressed air tank of air-transformer type located outside the long tube through the supplying hose longer than the long tube to be coated; and the paint and the air are respectively heated to a predetermined temperature in the course of being delivered to the nozzle for being sprayed therefrom. It enables the paint to be sprayed under the predetermined atomization condition constantly, eliminating the necessity of varying the solvent ratio for adjusting the viscosity of the paint. Inevitable varying of the film thickness, gathering of the paint to a lower place, insufficient curing of the paint, defects of coated film owing to the remelting of the paint, and the environmental pollution due to the variation of solvent ratio in the midway of a coating process have been effectively eliminated. A practical coating method has thus

been established which is completely free from the changeable ambient conditions which affect the coating outcome. This invention can be applied, therefore, to a protective or anti-corrosion coating of the already installed condenser tubes in a running plant under different conditions, which has solved the problems to hamper traditionally the coating of the tubes under operation with a uniform thickness film.

Further, the present invention provides an apparatus or a tool for coating the inner surface of tubes, specifically the structure of a novel spray nozzle which is capable of forming a coated film of uniform thickness either in the circumferential and axial direction on the inner surface of tubes and performing a stable operation even in a continuous coating work. This novel spray nozzle is preferably applied to the above-mentioned method to be disposed on the tip of the supplying hose. The feature of this novel spray nozzle can be summarized as follows. In a spray coating apparatus or a tool, having a spraying nozzle for spraying a coating or paint for being gradually shifted or moved in a tube-to-be-coated while executing the spraying operation, a nozzle insert having a prism portion, on the external surface of which at least one spiral groove being formed, is being inscribed within a hollow cylindrical space of a nozzle cap of the spray nozzle. In a spray nozzle of such a structure, (1) a plurality of straightly extending long spaces or grooves formed between the sides of the prism portion and the inner surface of the nozzle cap, and (2) at least one spiral groove formed on the surface of the prism portion, constitute routes or passages for the atomizing or nebulizing gas so as to impart it a straightly going force and a spirally advancing force. The coating or paint supplied through a hole bored in the central portion of the nozzle insert can be spirally sprayed when leaving the tip or mouth of the spray nozzle.

According to this nozzle, the atomizing gas is imparted a straight going force and a spiral going force, owing to the axially elongated grooves, between the prism

portion and the inside surface of the nozzle cap, and the spiral groove. The paint can be, due to the double directional atomizing gas, spirally sprayed with a uniform thickness in the circumferential and axial direction of the tube-to-be-coated throughout the entire length thereof. This nozzle has eliminated the frequent overhauling of the spray nozzle which was conventionally inevitable due to the clogging of paint remnant and dust in the air pocket and other portions of the nozzle. This nozzle has enabled in this way a stable and continuous spraying operation for a long tube of small diameter, bringing about a good result of thin and uniform thickness of film in all direction of the tube interior. Specifically, in protective coating of condenser tubes used in a surface condenser for a thermal power station, which are as long as 5-40 meters and of small diameter such as 10-40 mmϕ, this invention is quite effective. This nozzle is capable of giving a coating film at a thickness of 10-30 μ to a condenser tube of the above-mentioned dimension, without deteriorating the heat transfer function of the tube at all, the most important feature as a heat exchanger.

Fig. 1 is an explanatory sectional view of a condenser in which this invention is preferably applied;

Fig. 2 is an axial sectional view of an apparatus in accordance with this invention;

Fig. 3 is a sectional view, in an axial direction, of another apparatus in accordance with this invention;

Fig. 4 is an axial sectional view of still another apparatus in accordance with this invention;

Figs. 5 and 6 are respectively a cross sectional view of a supplying hose employed in further apparatus in accordance with this invention and an exploded axial sectional view of the apparatus;

Figs. 7 and 8 are respectively a cross sectional view of a supplying hose employed in still further apparatus in accordance with this invention;

Fig. 9 is an axial sectional view of an essential part of an embodiment of a spray coating apparatus, including

a nozzle insert, of this invention;

Figs. 10-12 are respectively a cross-sectional view taken along the section line III-III, IV-IV, and V-V in Fig. 9;

Fig. 13 is an axial sectional view in elevation of a part of the nozzle insert in Fig. 9;

Fig. 14 is a side view seen from right side of the nozzle insert in Fig. 13; and

Fig. 15 is a schematic view showing how the inner surface of a condenser tube is coated with the apparatus in Fig. 9 of this invention.

With reference to the appended drawings detailed description of the preferred embodiments will be made hereunder.

A surface condenser 10 employed in a thermal power plant (station), being connected with a steam-turbine, is shown in Fig. 1, wherein a large cylindrical fluid-tight, sealable condenser shell 1 is divided into three chambers with a pair of condenser tube plates 2 and 3 disposed at either endwise biased portion. In the central portion sandwiched by the pair of plates 2, 3 thousands of or tens of thousands of condenser tubes 4 of copper alloy with the diameter of 10-40 mmϕ are parallelly disposed extending along the length of 5-40 m. On either end portion of the condenser shell 1 outside the tube plates 2, 3 condenser water boxes 6 and 7 is respectively formed.

On top of the condenser shell 1 (hereinafter simply called shell) a steam inlet 11 is disposed centrally located for receiving the exhaust steam from the steam turbine; on the lower side of the shell 1 a condensed water recovering (receiving) inlet 12 is made, similarly centrally located in the lateral direction, as can be seen in Fig. 1. In the condenser water box 6 on the left side of Fig. 1 a cooling water outlet 16 is provided on top of the shell 1; in the right side of the water box 7 a cooling water inlet 17 is provided on the lower side of the shell 1. A vent 13 is formed on one flank of the shell 1. The cooling water inlet

17 and the cooling water outlet 16 are respectively connected to a circulating water pump; the condensed water receiving inlet 12 is connected to a condensate pump; and the vent 13 is connected to an exhaust pump. These pumps are however not shown in the drawings. In short, the cooling water in a condenser 10 of this type is flowed through the condenser tubes 4 from right to left in Fig. 1, while the exhaust steam from the steam turbine is passed through the gap left among the condenser tubes 4 almost downwardly on the other hand, so as to perform a heat transference between the cooling water and the exhaust steam through the contact of both at the wall of the condenser tubes with a result of condensing the exhaust steam into water.

In making anti-corrosion coating of the whole length of the interior of such condenser tubes 4 in the condenser 10, a coating operator enters into one, or both when it is necessary, of the condenser water boxes 6, 7 on the end portion of the condenser 10 for operating the spray nozzle there. Assuming a concrete example where the operator works in the water box 6, he inserts a supplying hose 22 having a spray nozzle 21 on the tip thereof and respective passages for paint and compressed air into one side opening of a condenser tube 4 and continues to push it deeper therein until the spray nozzle 21 reaches, passing through the whole length (5-40 m) of it, the other end opening of the condenser tube 4 on the side of the water box 7. When the spray nozzle 21 has reached the destination, the supplying hose 22 begins to be drawn back with a mechanical means at a predetermined speed, upon starting the spraying of the paint. The paint to be sprayed and the compressed air are supplied from a paint reservoir (not shown) and an air transformer (not shown) respectively situated in the water box 6 or outside the condenser 10, through the separate passages. The paint is atomized for being sprayed at the nozzle 21 with the aid of the compressed air in a well known way. With the starting of spraying paint the nozzle 21 is pulled back by the earlier stated mechanical means steadily from the water box 7 toward the water box 6

while continuing the coating operation regularly throughout the whole length of the condenser tube 4. Upon completely pulling back the supplying hose 22 to the starting place spraying of the paint is ceased by the stoppage of supplying the paint and the compressed air. At the finish of painting of a first condenser tube 4 similar operation begins with a second condenser tube 4, and then with a third. The protective coating of the lots of condenser tubes 4 is continued in the same method until all of them in the condenser 10 are coated.

Such a coating process which is susceptible to various environmental conditions, such as temperature, humidity, etc., requires to be maintained at an optimum situation for forming a non-defective and uniform thick film. The present invention is aimed at obtaining an optimum spraying condition of the paint through nebulization or atomization of the paint at the spray nozzle 21 by means of supplying the paint and the compressed air, through the respective passage in the supplying hose 22, heated at a most preferable temperature for coating such as 15-35^{o}C.

As a method for heating the paint or the compressed air in the supplying hose 22 according to this invention, there are variety of effective ones available such as directly heating them by an electric heating means, for example, an electrical heating wire; cycling a heating medium in the supplying hose 22, or combination of those means, etc.

What is illustrated in Fig. 2 is an example of electrical heating means, being effective in realizing this invention and extremely simple in structure, wherein a front end portion of a nozzle is shown as an axial sectional view. The paint and the compressed air delivered thereto are heated there up to a predetermined temperature in a very short time.

According to Fig. 2, a spray nozzle 21 of ordinary structure is provided with a paint passage 21a in the central part and an air passage 21b embracing the former completely in it for spraying the paint by the action of the compressed air in atomization state. The supplying hose 22 to which the

nozzle 21 is attached is composed of a flexible hose 23 of double-structure leading the paint and the compressed air from outside the condenser tube 4 and a metallic heating pipe 24 of a predetermined length for heating the paint and the compressed air delivered thereto by the flexible hose 23.

The flexible hose 23 is constituted of an inside tube 23a made of polyvinyl chloride or the like for forming a paint route or passage and a flexible outside tube 23b made of hard plastic for example hard nylon or metallic flexible tube being concentric with the inside tube 23a to form an air route or passage therebetween. The heating pipe 24 which is attached with a joint 25 to the tip of the flexible hose 23, just like the latter, of double structure consisting of an inside pipe 24a and an outside pipe 24b. The inside pipe 24a is communicated with the inside tube 23a for forming a paint passage and the outside pipe 24b is communicated with the outside tube 23b for forming an air passage. Around the external surface of the inside pipe 24a a sheathed heater 26, for example sheath element 0.2-1 mmϕ and external diameter of the sheath 1.6-4.8 mmϕ, as an electric heating means is wound like a coil for heating directly the compressed air and indirectly, via a pipe wall of the inside pipe 24a, the paint under the control of a thermostat 27 attached to the tip of the sheathed heater 26. Power supply to the sheathed heater 26 is executed by a lead wire 28 extending through the outside tube 23b so far as to get out of the condenser tube 4; and the sheathed heater 26 is covered by a stainless-steel-made tube for being completely separated from the inside pipe 24a for feeding the paint, so there is no likelihood and no danger of a fire or an explosion. The above-mentioned heating pipe 24 is, at the tip thereof, connected to the nozzle 21 by way of a joint 29; the inside pipe 24a is connected to a paint passage 21a of the nozzle 21 and the outside pipe 24b is connected to an air passage 21b of the nozzle 21.

With such a structure, the paint and the compressed air delivered from outside the condenser tube 4 through the flexible hose 23 are respectively heated to a predetermined

temperature by the sheathed heater 26 at the heating pipe 24 for being immediately led to the nozzle 21, where the heated paint is sprayed in atomization by the action of the similarly heated compressed air. Incidentally, for heating the paint and the compressed air from 5°C to 30°C respectively, under conditions where the compressed air gushing (blowing) amount is 300 ℓ/min. and the paint discharging amount is 100mℓ/min and the heater 26 has a length of 360 mm., it has to be maintained at 150°C under the control of the thermostat 27. The length of the heating portion with the sheathed heater 26, i.e., the length of the heating pipe 24 may be suitably determined depending upon the compressed air amount, the paint discharge amount, the material quality of the heater's inserting portion, the heating condition, etc., with a variety of choice, for example, from ordinary length of approx. 300 mm to an extremely long case of covering the whole length of the supplying hose 22. In a case wherein the paint and the compressed air are heated ranging the whole length of the supplying hose 22, the same pipe is preferable to be flexible over the whole length from the view point of easiness of its handling, and required to be made of a material sufficiently resistant to a temperature of 40-60°C. It is effective to employ a heat-resistant plastic for both the inside tube and the outside tube of the supplying hose 22 or employ a metallic flexible tube for the outside tube.

In Fig. 3 another embodiment of this invention, wherein the similar sheathed heater to that in Fig. 2 is employed, is shown. A spray nozzle 31 is connected therein by way of a joint 30 to a flexible hose 23 as the supplying hose 22. On one end of the joint 30 a nozzle insert 31a with a paint passage in the central part is coaxially threaded, and a nozzle cap 31b is threaded on the external side of the joint 30. A gap formed between the nozzle insert 31a and the nozzle cap 31b constitutes a passage for the compressed air. On the other end of the joint 30 the outside tube 23b, which delivers the compressed air in the flexible

hose 23 of double structure, is firmly fitted; and at the same time on a metallic inner tube 30a, which is fitted into a central through-bore of the joint 30, the inside tube 23a for feeding the paint is firmly fitted. On the external surface of the metallic inner tube 30a fitted into the joint 30 a sheathed heater 32 is wound about for heating the paint and the compressed air by being supplied with power through a lead wire 28 running along the outside tube 23b, just like in the previous embodiment. As the length of the heating portion in the structure of this embodiment coincides with that of the inner tube 30a wound by the sheathed heater 32, which facilitates the adjustment of the length thereof relatively easily. The outside tube 23b of the flexible hose 23 can be utilized, as it is, as an outside tube to the inner tube 30a, advantageously eliminating the putting of a separate metallic pipe as in Fig. 2.

Still another embodiment with an electrical heating means such as a sheathed heater is shown in Fig. 4, wherein a flexible hose 23 as the supplying hose 22 is, unlike the previous ones, of triple structure. Between an inside tube 23a and an outside tube 23b a median tube 23c is coaxially disposed. On the external surface of the inside tube 23a a sheathed heater 33 is wound about, while a gap formed between the inside tube 23a and the median tube 23c is filled with a suitable heat conducting medium such as air, water, etc., which functions along with a sheathed heater 33 to heat the paint fed through the inside tube 23a and the compressed air fed through the outside tube 23b respectively to a predetermined temperature.

In such a structure, the paint and the compressed air in the flexible tube 23 are maintained at a suitable temperature, even when the coating operation is temporarily suspended and the heating with the sheathed heater 33 is stopped by any chance, by the heat kept in the heat conducting medium. The paint and the compressed air are advantageously protected from being affected by the ambient conditions immediately. This structure is particularly useful in

a system wherein the heating means is disposed ranging the whole length of the supplying hose 22.

Several embodiments described above all relate to systems in which an electrical heating means is adopted; this invention is however applicable to another type of apparatus wherein heated fluid is cycled in the supplying hose.

In an embodiment shown in Figs. 5 and 6 a flexible hose 40, which extends from outside of the condenser tube 4 to a predetermined position in the condenser tube 4, is constituted of an outside tube 41 of hard plastic for forming a compressed air passage 41a, a median tube 42 for forming a paint passage 42a, and an inside tube 43 of heat resistant plastic for forming a passage (forward and backward) for heated fluid. Three of these are all coaxially arranged to make a triple structure. And in the inside tube 43 a long partition is disposed in a diametric direction ranging the whole length of the tube to divide the inside into two parts, i.e., forward flowing passage 43a and a backward flowing passage 43b. To the end portion of the flexible hose 40 a spray nozzle 46 is attached by way of a suitable joint 45. The inside tube 43 is not blocked by the joint 45, but the forward flowing passage 43a and the backward flowing passage 43b thereof are communicated to each other only in the end portion, that is, in the attaching portion of the spray nozzle 46. Accordingly, warm and heated water from a water supplying tank similarly disposed as the paint reservoir outside the condenser tube, or heated air (or other heated fluid) from a suitable heating means comes through the inside tube 43, specifically through the forward flowing passage 43a, to the vicinity of the attaching portion of the spray nozzle 46, where it is flowed back through the backward flowing passage 43b to outside of the condenser tube 4. In the cycling course of such a flowing forward and backward of the heating medium through the forward flowing passage 43a and the backward flowing passage 43b, the paint and the compressed air flowed through the respective passage (41a,

42a) are heated by the heating medium up to a predetermined temperature.

When such a cycling system of a heating medium is adopted, the amount of the medium used in the cycling is, in contrast to the amount of the medium in a direct heating type hot air system, small and economical because of a possible small size of the heater capacity, outside the condenser tube 4.

If a metallic heating tube of small length, like one in Fig. 2 designated with 24, is attached in the above embodiment to a portion adjacent to the nozzle 46, the paint and the compressed air will be further stabilized in their required temperature.

The same object can be attained by incorporating a sheath heater in the inside tube 43 and by cycling only the air therethrough.

Another example of heating by means of heated fluid can be seen in Fig. 7 or Fig. 8, either being effective.

In a half-splittable type flexible hose 50 of hard plastic, shown in Fig. 7, a pair of small diametered tubes 51, 52 of heat resistant vinyl resin are respectively inserted into a pair of sections 50a, 50b formed in the flexible hose 50. Either one, for example, 51 is adapted to pass the paint and the other may be adapted for passing the compressed air; and one section 50a is used as a forward flowing passage for the heating medium and the other section 50b as a backward fluid passage of the same. In this embodiment sheathed heaters may be wound about each of the small diametered tubes 51, 52 in a coil style ranging the whole length of the tube for heating the paint and the compressed air. In an embodiment shown in Fig. 8, a supplying hose 53 is divided into four sections, one pair of diagonally positioned sections 53a, 53c are used for the paint and the compressed air feeding, and the other diagonally positioned sections 53b, 53d are used for the forward flowing passage and the backward flowing passage of the heating medium.

Those supplying hoses 50, 53 are all connected via a

suitable joint to a spray nozzle, and the heating medium is flowed through a forward flowing passage (50a, 53b), which is respectively one of the passages in the supplying hose, up to the vicinity of the connecting portion of the spray nozzle, where it is flowed back through respective backward flowing passage (50b, 53d) outside the system. While the heating medium is thus cycled from the forward flowing passage to the backward flowing passage, the paint and the compressed air are respectively heated, by way of the tube or hose wall, up to a predetermined temperature, so that the paint may be sprayed by the compressed air in a good spraying condition.

Futher, a spray gun preferably employable in the present invention, shown in Figs. 9-14, is provided with a cylindrical outer casing 61, which is on either male-screwed end portions thereof threaded by a center guide 62 and 63, as illustrated in Fig. 9. The center guides 62 and 63 are all of hexagonal form in cross section, having a dimension just inscribable in the inner surface of a tube-to-be-coated. The hexagonal edge portions of the center guides 62, 63 are good for guiding the spray gun itself by being slided reciprocally along the inside of the tube.

On one end of the outer casing 61 a nozzle cap 64 is concentrically fastened thereto at a flange 64a thereof by the center guide 62.

An inner casing 65 having an external diameter smaller than the internal diameter of the outer casing 61 by a predetermined amount is disposed inside, and concentrically with, the outer casing 61. To the right end, in Fig. 9, of the inner casing 65 a nozzle insert 68 having a through bore 68a in the axis thereof is threaded into. A sheathed heater, as not shown, such as that illustrated in Fig. 2 is wound about on the external surface of the inner casing 65. The nozzle insert 68 is provided with a hexagonal prism portion 68b which is inscribable in a hollow cylindrical portion 64b of the nozzle cap 64 and a conical portion 68c faced to a hollow conical space 64c of the nozzle cap 64 with a predetermined gap. Between the inner surface of the

hollow cylindrical portion 64b and each of six flat sides of the hexagonal prism portion 68b six straight but arch ceiling shaped spaces 69 are left lengthwise as seen in Fig. 12; on the surface of the nozzle insert 68 a spiral groove 70 is inscribed with a certain angle α to the axis thereof, as can be seen in Figs. 13 and 14. It signifies therefore that two kinds of flow passages for the blowing or atomizing gas, for example compressed air, are formed between the nozzle cap 64 and the nozzle insert 68, i.e., the six straightly elongated spaces 69 (which will be called straight grooves) and three spiral grooves 70.

The left end (in Fig. 9) of the inner casing 65 is threaded in a boss 61a of the outer casing 61 as to leave a predetermined space 71 between the inner casing 65 and the outer casing 61. Through a suitable number of through-holes 61b formed in the boss 61a and the space 71, a passage for the atomizing (spraying) gas is made in the direction toward the nozzle cap 64. The atomizing gas is supplied by an air hose 76 attached to the open end of the center guide 63; the air hose 76 is usually made into a double hose 75, i.e.a supplying hose, containing a paint supply passage 66 therein, for being inserted deep into, and drawn back out of, a tube to be coated. The boss 61a is provided with a fitting 67 threaded thereinto, to the other end thereof the paint supply passage 66 is intended to be connected. The fitting 67, the inner casing 65, and the through-bore 68a in the nozzle insert 68 constitute a route for supplying the paint.

In the spray gun of such a structure the paint is supplied through an inside route of a double tube formed by the center guide 63 and the fitting 67, and atomizing gas led by the air hose 76 is supplied through an outside route of the double tube. The paint coming through the fitting 67, the inner casing 65, and the through-bore 68a of the nozzle insert 68 is sprayed out of a tip portion 73 of the through-bore 68a; and the blowing gas such as compressed air is led forward through the through-holes 61b and the space 71, and is further given a straight going force in the straight

grooves 69 and a spirally advancing force through the spiral groove 70, before it is blown, getting through the space between the conical portion 68c of the nozzle insert 68 and the hollow conical space 64c of the nozzle cap 64, out of a gas blowing portion 72. This blowing (or spraying) gas atomizes the paint gushing out of the tip portion 73 of the through-bore 68a of the nozzle insert 68, while spiraling the same, which enables the paint to be sprayed uniformly toward the inner surface of the tube-to-be-coated. By means of shifting backwards the spray gun itself of this type, once inserted deep through to the other end opening of the tube to be coated, at a constant speed, while spraying the paint in atomization, along the inside of that tube (leftward direction in Fig. 9), a method of coating the inner surface of a long tube of small diameter throughout the entire length thereof has just been established.

Describing more specifically, for coating the inner surface of a long condenser tube 81 of small diameter, as shown in Fig. 15, a double hose 75, having a spray nozzle 80 of this invention on the tip thereof, is inserted into the condenser tube 81 from one end opening 81a thereof as far as the other end opening 81b throughout the whole length (5-40 m) of the condenser tube 81. The moment when the spray nozzle 80 has reached the other end opening 81b of the condenser tube 81 spraying of the paint is commenced with atomization. The paint and the atomizing gas are independently supplied through their respective passage, as mentioned above, before reaching the spray nozzle 80, where the former is sprayed in atomization due to the double directional spraying force of the latter, i.e., straight and spiral. As soon as the spraying of the paint is commenced, the double hose 75 is drawn back while spraying the paint from the spray nozzle 80, by means of a suitable mechanical means, at a predetermined constant speed from the other end opening 81b toward the one end opening 81a of the condenser tube 81. During this shifting or movement of the spray nozzle 80, due to the drawing back of the double hose 75 through the

condenser tube 81, the inner surface thereof is gradually and regularly coated with the atomized paint. The whole length of the condenser tube 81 can thus be coated with a uniform thickness from one end to the other end thereof. When the spray nozzle 80 has returned to the one end opening 81a, the supplying of the paint and the atomizing gas is suspended to stop the coating operation. When one condenser tube 81 is finished coating in this way another and a third tube will be coated in order successively in a similar way. By this continuous and repeated protective coating operation, a condenser having a large number of condenser tubes can be coated or re-coated on the inner surface thereof quite smoothly and effectively.

The shape of the spiral groove or grooves 70 formed (inscribed) on the external surface of the nozzle insert 68 may be varied according to the internal diameter of the condenser tube 81 to be coated. It is appropriate in normal cases to determine the twist angle α formed between the spiral groove 70 and the axis of the nozzle insert 68 (see Fig. 13) in the range of 15-60°. And it is preferable to set the spray angle θ, that is a half of the vertical angle of the conical portion 68c of the nozzle insert 68, within the range of 5-45° so as to ensure the best spraying condition at a place 200 mm distant from the tip of the spray nozzle 80.

In the above embodiment the nozzle insert 68 is provided with the hexagonal prism portion 68b which is easy in machining, but the shape of this prism portion is by no means limited to the hexagon. It is of course variable in various suitable ways to those skilled in the art, for example, quadrangular or octangular prism and so on, without any difficulty.

This invention is by no means limited to the above-mentioned methods and apparatuses, but it can be varied and modified in many ways within the spirit of this invention by those skilled in the art. As to the paint to be used in this invention, variety of ones suitable to the coating of long tubes of small diameter can be numerated; among those some

organic synthetic resin coatings or paints, which may be cured at a room temperature or its neighborhood, are preferable for the purpose of anti-corrosion coating. As their base or vehicle alkyd resin, vinyl chloride resin, polyurethane resin, epoxy resin, silicone resin, acrylic resin, etc., are exemplified.

Before concluding the description an experiment for clarifying the effect of this invention will be disclosed hereunder.

In a condenser provided with 6200 condenser tubes of copper alloy (JIS H 3300), whose dimension was 25.4 mm in external diameter, 22.9 mm in internal diameter, and 15330 mm in length, a protective coating method was applied to 1500 condenser tubes out of all.

First of all the condenser tubes to be coated were repeatedly cleansed fifty times by sponge balls with silicon carbide grains stuck thereon, followed by water cleansing, draining and drying.

After the above-mentioned cleansing the tubes were coated by the apparatus shown in Fig. 2 for protecting from corrosion. It was carried out under rather severe condition to the eyes of those skilled in the art particularly:

temperature: 5-10°C
humidity : 60%

The paint used was:

kind : zinc chromate primer
viscosity: 20 sec. by No. 4 Ford viscosity cup (15°C)

The coating conditions were:

amount of the paint discharged: 60 mℓ/min.
amount of the air supplied : 300 ℓ/min.
shifting velocity of the nozzle: 500 mm/sec.

The drying condition:

the wind velocity: 2.5 m/sec., 24 hours

After the anti-corrosion coating, the result was examined in all of the 1500 condenser tubes. A part of the tube end 1.5 m from the end opening was visually examined

with a tube examining scope. On the side from where the wind gets out, some flowing downward or gathering of the paint was found within 1 meter range from the end opening in only ten tubes out of the 1500 tubes.

The result may be said surprisingly excellent considering the severe conditions under which the coating was carried out.

In a measuring test of the thickness of the coated film on the lower side of the tube at a position 500 mm from the end opening executed with a film-thickness meter of eddy current type, the results were so good as 18.5 µ in an average thickness and 2.5 µ in a standard deviation.

CLAIMS:

1. A method for coating the inner surface of a long tube of small diameter by spray coating, wherein a spray nozzle is shifted from one end opening of the long tube to the other end opening thereof, characterised by comprising:

inserting a supply hose, longer than said long tube, provided with said spray nozzle attached to the tip thereof and respective passages for conducting liquid coating medium and compressed gas to said nozzle, into said long tube;

heating said liquid coating medium and said compressed gas within said respective passages; and

spraying the heated liquid coating medium from said nozzle by the action of the heated compressed gas.

2. A method claimed in Claim 1, characterised in that the long tube to be coated is a condenser tube having an inner diameter in the range of 10-40 millimeters and a length in the range of 5-40 meters and the inner surface thereof is coated with a coating film of 10-30 μ thickness.

3. A method claimed in Claim 1, or Claim 2, characterised in that the liquid coating medium and the compressed gas to be supplied to said nozzle are heated to a temperature of 15^{o}C to 35^{o}C within the respective passages of the supply hose.

4. A coating apparatus for coating the inner surface of a long tube of small diameter by spraying a liquid coating medium in atomization while being shifted from one end opening to the other end opening thereof, characterised by comprising:

a supply hose provided therein with respective passages for supplying a liquid coating medium and compressed gas;

a spray nozzle attached to the tip of said supply hose; and

electric heating means disposed at least in the neighbourhood of the region where said nozzle is attached to said supply hose for heating the liquid coating medium and the compressed gas,

5. A coating apparatus as claimed in Claim 4, characterised in that said supply hose is of double structure, having an outside tube on the outer side for forming a passage for the compressed gas and an inside tube on the inner side for forming a passage for the liquid coating medium, and longitudinally composed of two portions, one being a heating pipe portion of double structure, on the external surface of an inside pipe thereof an electrical heating means is wound about, to be connected to said nozzle, and the other being a flexible hose portion of double structure for supplying the liquid coating medium and the compressed gas from the outside of the long tube to said heating pipe portion.

6. A coating apparatus claimed in Claim 4, characterised in that said supply hose is of triple tructure composed of an inside tube, a median tube, and an outside tube, and said electrical heating means is disposed in a gap formed between said inside tube and said median tube which gap contains heat conducting medium, so that in use said liquid coating medium and said compressed gas to be supplied to said nozzle are heated by said electrical heating means by way of said heat conducting medium.

7. A coating apparatus claimed in any one of Claims 4 to 6, characterised in that said electrical heating means is a sheathed heater.

8. A nozzle for apparatus for continuously and gradually coating the inner surface of a tube by spraying, while being shifted inside along the axial direction of said tube, characterised in that said nozzle comprises:

a nozzle cap consisting of a hollow cylindrical portion, a hollow conical portion extending therefrom, and an opening at the tip of said hollow conical portion for blowing gas therefrom; and

a nozzle insert, which is adapted to be installed in said nozzle cap, consisting of a prism portion provided with at least one spiral groove on the external surface thereof, a conical portion extending from said prism portion, and a supply passage for liquid coating medium extending therethrough along the axis thereof, the nozzle insert being adapted to fit within the hollow cylindrical portion of the nozzle cap with the conical portion thereof spaced by a small gap from the inner surface of the hollow conical portion and with a plurality of generally straight elongated grooves or spaces defined between the lateral walls of the prism portion and the inner cylindrical surface of the nozzle cap,

whereby atomizing gas when supplied through the space between said nozzle cap and said nozzle insert will be given a straight going force by the plurality of straight elongated grooves or spaces formed between the inner surface of said nozzle cap and each of the sides of said prism portion and a spirally going force by said spiral groove or grooves, and will emerge through said tip opening so as to spirally spray in atomization the liquid coating medium supplied through the passage along the axis of said nozzle insert.

9. A nozzle claimed in Claim 8, characterised in that said prism portion of said nozzle insert is of hexagonal shape in the cross section, and said spiral groove formed on the external surface of said prism portion is inclined to the axial line of said nozzle insert at a twist angle in the range of 15-60°.

10. A nozzle as claimed in Claim 8 or Claim 9, characterised in that the spiral groove formed on the external surface of said prism portion extends sufficiently far onto the conical portion of said nozzle insert such that the spiral flow of the atomizing gas is led to said gas blowing opening of said nozzle cap.

11. A nozzle as claimed in any one of Claims 8 to 10, characterised in that one half of the vertical angle of said conical portion of said nozzle insert is in the range of 5-45°.

FIG. 1

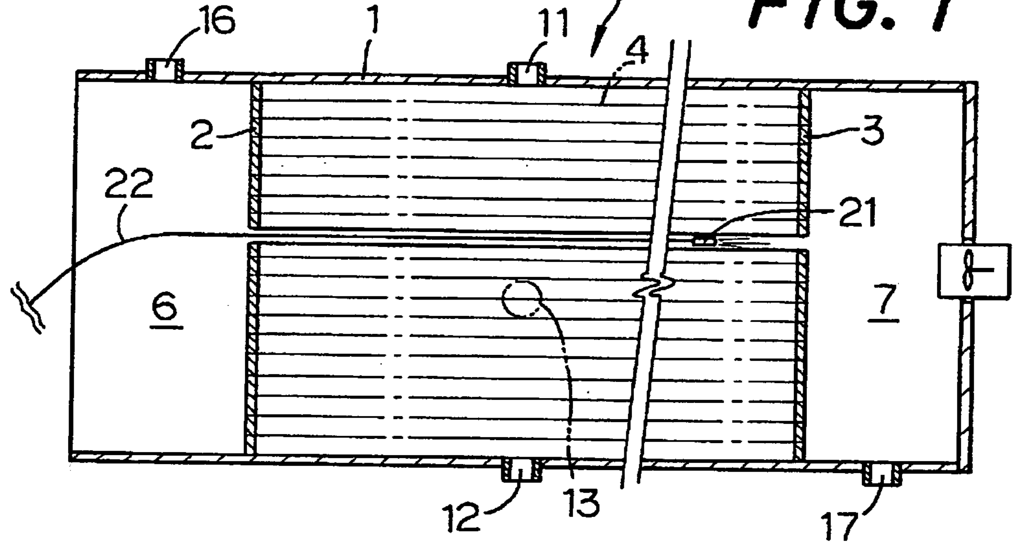


FIG. 3

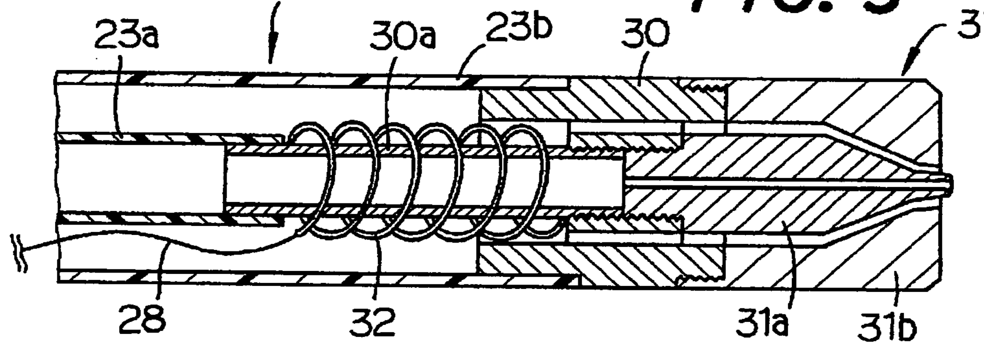
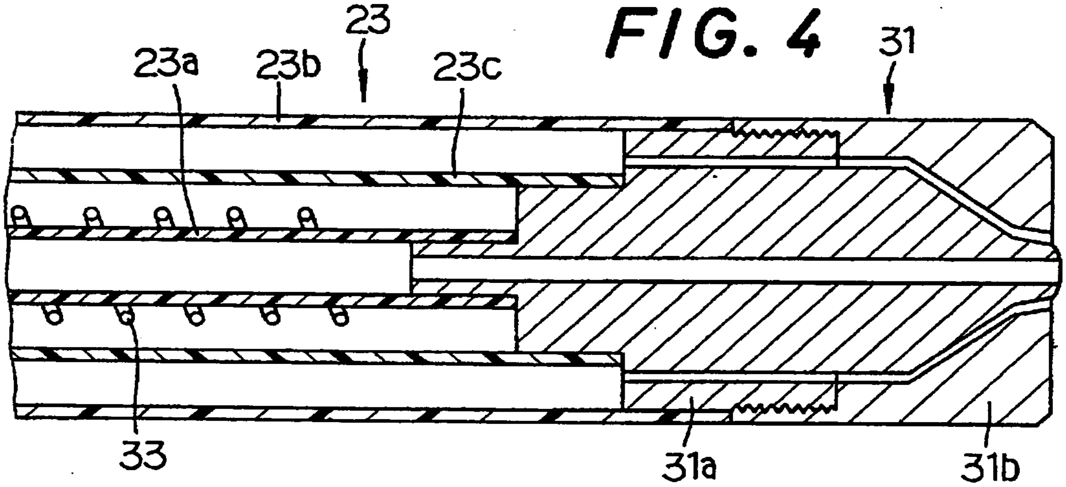


FIG. 4



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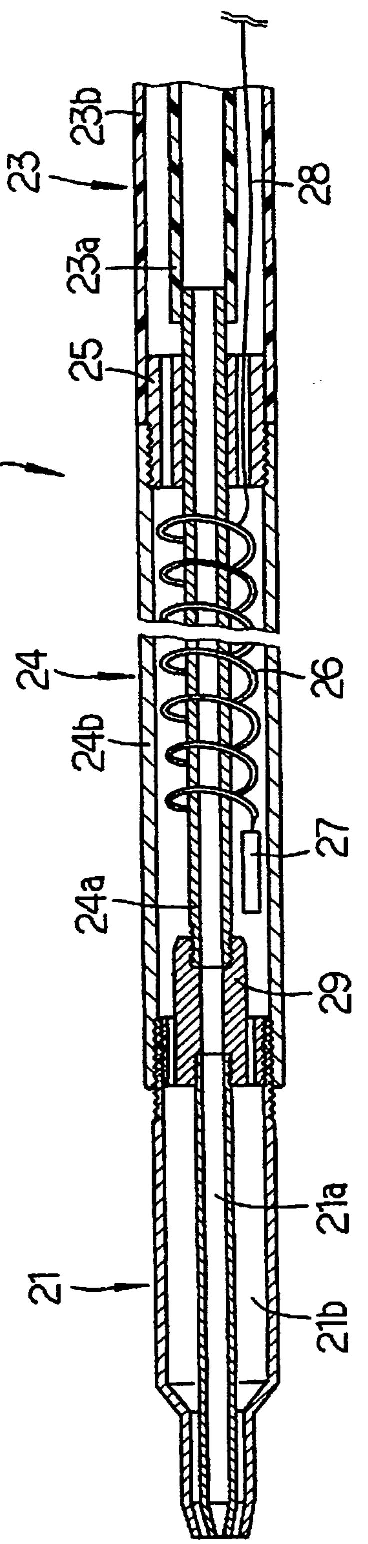

FIG. 2

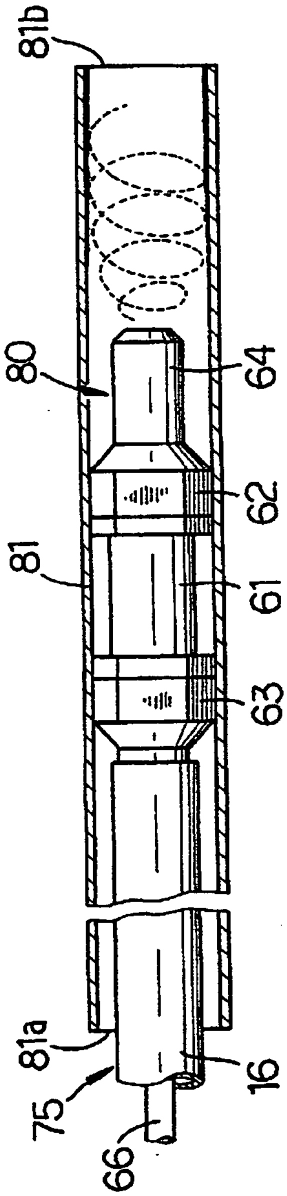

FIG. 15

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FIG. 5

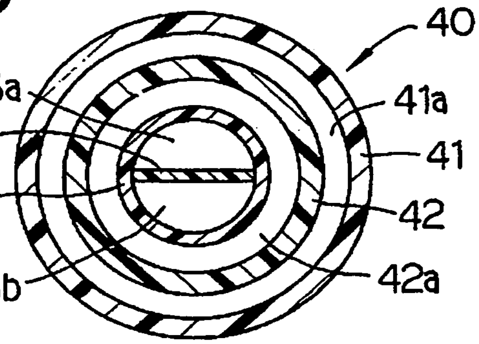


FIG. 6

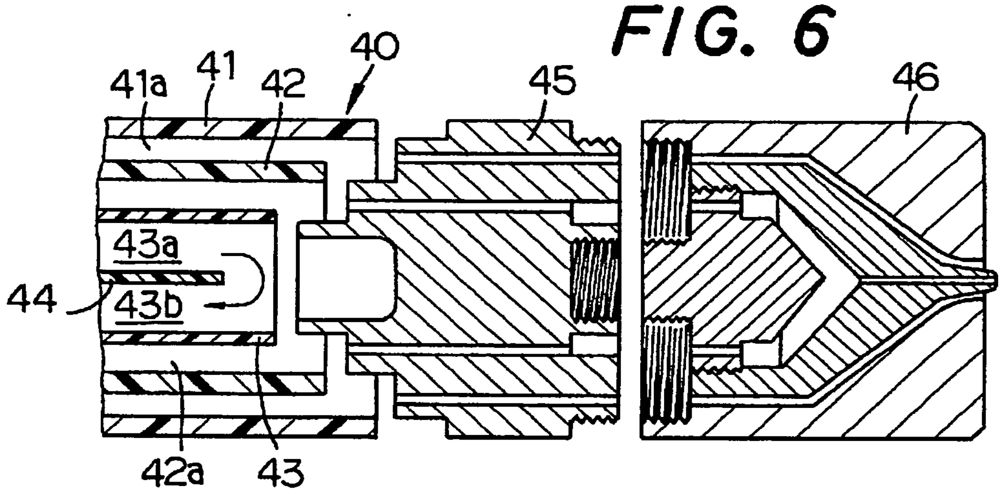


FIG. 7

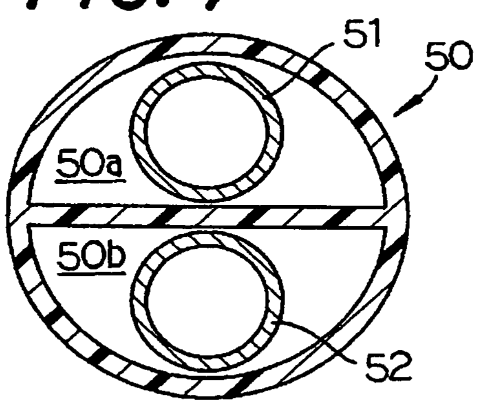
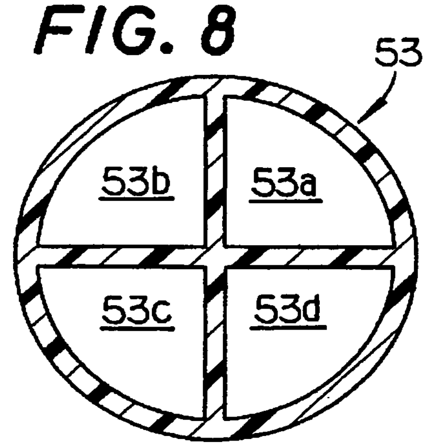


FIG. 8



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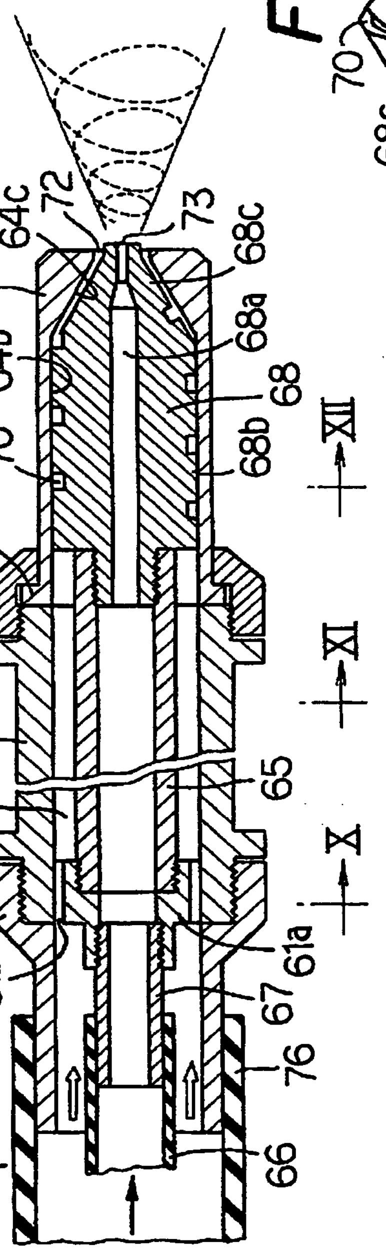

FIG. 9

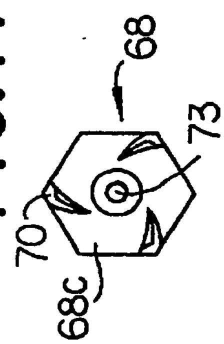

FIG. 14

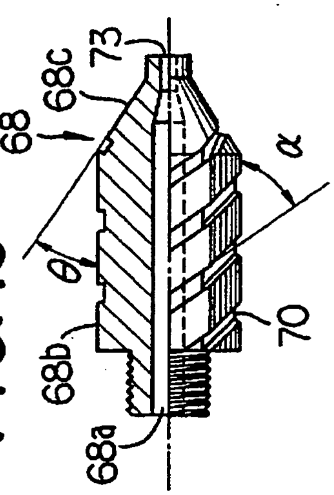

FIG. 13

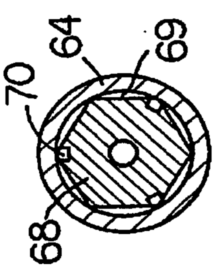

FIG. 12

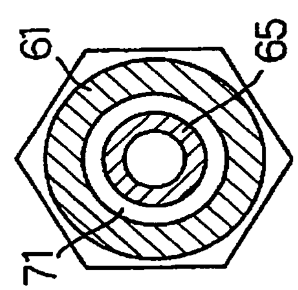

FIG. 11

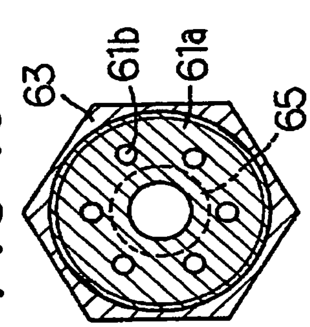

FIG. 10

European Patent Office

EUROPEAN SEARCH REPORT

0028088

Application number EP 80 30 3602

Category	DOCUMENTS CONSIDERED TO BE RELEVANT Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.)
	US - A - 2 576 942 (J.P. JAKOB) * Column 5, lines 37-71; figures 1,2,4 * --	1,4	B 05 B 13/06 7/16 7/10 B 05 D 1/02 7/22
	FR - E - 88 147 (POTEL) * Complete document * --	1,4,5,7	
	US - A - 2 314 329 (W.M. ERICSON) * Column 2, lines 13-33; figures 1,4 * --	4-7	TECHNICAL FIELDS SEARCHED (Int. Cl.) B 05 B B 05 D
	US - A - 2 520 397 (M.C. GREEN) * Column 4, lines 43-66; figures 1,3,8 * --	1,4,8	
	US - A - 2 984 421 (J.W. HESSION) * Complete patent * --	8,10,11	
	DE - C - 466 932 (J. WEINLICH) * Figure 2A * ----	8,10	CATEGORY OF CITED DOCUMENTS X: particularly relevant A: technological background O: non-written disclosure P: intermediate document T: theory or principle underlying the invention E: conflicting application D: document cited in the application L: citation for other reasons
X	The present search report has been drawn up for all claims		&: member of the same patent family, corresponding document

Place of search	Date of completion of the search	Examiner
The Hague	26-01-1981	COLPAERT